USAARL Report No. 2010-16

The Effect of Blast Exposure on Sleep and Daytime Sleepiness in U.S. Marine Corps Breachers

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August 2010

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REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
30-08-2010	Final	

4. TITLE AND SUBTITLE
The Effect of Blast Exposure on Sleep and Daytime Sleepiness in U.S. Marine Corps Breachers

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U. S. Army Aeromedical Research Laboratory
P. O. Box 620577
Fort Rucker, AL 36362-0577

8. PERFORMING ORGANIZATION REPORT NUMBER
USAARL 2010-16

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U. S. Army Medical Research and Materiel Command
504 Scott Street
Fort Detrick, MD 21702-5012

10. SPONSOR/MONITOR'S ACRONYM(S)
USAMRMC

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Traumatic brain injury resulting from blast exposure is an increasingly common problem among Soldiers returning from combat deployment. In order to understand the extent of damage resulting from blast exposure, this study examined students and instructors at the United States Marine Corps Methods of Dynamic Entry School during a two week training period. The results of the study suggest that actigraphy and subjective sleep measures are sensitive to changes in sleep quality/quantity as well as daytime sleepiness over the training session. The extent to which these changes are associated with blast exposure rather than other factors related to the training period will be explored further in a large scale study of breacher crewmen.

15. SUBJECT TERMS
breacher crewmen, sleep, blast exposure

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
UNCLAS	UNCLAS	UNCLAS	SAR	23	Loraine Parish St. Onge, PhD
					19b. TELEPHONE NUMBER *(Include area code)* 334-255-6906

Reset

Acknowledgements

The authors would like to express their sincere gratitude to the following people for their contributions to this project.

- MSgt Shane Languard and CWO5 Bradley Garfield from the USMC Methods of Dynamic Entry School for their support and coordination of data collection for this project.
- Ms. Elizabeth Stokes for help with administrative matters.
- Dr. Loraine St. Onge for her editorial assistance.
- Dr. Art Estrada and CPT Michael Dretsch for their administrative support.
- CPL Joseph White and SGT William McGillberry for their assistance with the data collection.
- Dr. Carol Chancey, Mr. Joe McEntire, Mr. Fred Brozoski, Mrs. Catherine Webb and Mrs. Katherine Hewett for their assistance in the development of the protocol.

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Introduction

Soldiers are frequently exposed to blast explosions during combat deployments. Improvised explosive devices (IEDs) are common weapons used by insurgents against American Warfighters, the blast impact from which may result in a traumatic brain injury (TBI) in nearby Soldiers. TBI is increasingly common and has been suggested to be the signature injury of the wars in Afghanistan and Iraq (Crooks, Zumsteg, & Bell, 2007). In order to study the impact that blast exposure has on short and long term functioning, U.S. Marine Corps breacher training provides an available surrogate for combat blast exposure given that breachers are routinely exposed to blast during training. Anecdotal evidence from breachers suggests that daytime sleepiness increases and sleep quality decreases after a period of blast exposure. The present study served as a pilot study of students and instructors at the United States Marine Corps (USMC) Methods of Dynamic Entry School. The study took place during a two week training period. The purpose of the study was to document any changes in sleep quality, quantity, and daytime sleepiness, and also to explore the suitability of instruments for use in future research.

Military significance

The exact number of Soldiers who sustain a TBI is unknown, though a recent study by RAND Corporation estimated 19.5 % of U.S. Soldiers returning from Iraq and Afghanistan have a probable TBI (Tanielian & Jaycox, 2008; Tanielian et al, 2008). In a study conducted by Hoge, et al. (2008), a survey of 2525 soldiers who were active in Iraq revealed that nearly 15 % reported an injury during deployment that involved loss of consciousness, a characteristic sign of TBI. In addition, results indicated Soldiers with mild TBI reported significantly higher rates of physical and mental health problems than did Soldiers with other injuries. Disruptions in sleep patterns are prevalent after brain injury and can be troublesome for TBI sufferers, especially when the sufferers are Soldiers at war. Some of the sleep problems reported by those suffering from brain injury include insomnia, excessive day time sleepiness, premature onset of waking, and delayed onset of sleep (i.e., difficulty falling asleep). These sleep problems can detrimentally affect operational readiness thus justifying the need for research to identify the severity of sleep disruptions associated with blast exposure and blast injury.

There are a number of injuries that can result from an explosion or exposure to blast which are classified as 1) primary blast injury which is an injury caused by a blast wave, 2) secondary blast injury which is ballistic trauma, 3) tertiary injury which results from displacement of either the victim or environmental structures, and 4) quaternary which includes burns, toxins, and radiological contamination. The type of injury relevant to this study is primary blast injuries which are a resultant of the blast wave entering the body where it becomes two forms of potentially damaging energy; stress waves and shear waves (Ritenour, & Baskin, 2008).

Research shows support for a blast-induced brain injury. Unfortunately, very little is understood about traumatic brain injury resulting from primary blast injury and in general, very little data exist on the effects of blast exposure (and repeated exposures) and no experimental data exists related to the effect of blast exposure on sleep. USMC breachers provide a unique opportunity for studying the effects of blast exposure on sleep, specifically during a training period. In Methods of Dynamic Entry School, breachers learn how to apply explosives as a

means of gaining access to barricaded structures. This training period presents a special opportunity to gather data on subjects in a fully characterized, controlled blast environment. By studying students and instructors at Methods of Dynamic Entry School, the effects of repeated blast exposures on sleep can be characterized. These data may, potentially, also be extrapolated to improve our understanding of non-penetrating neurological injuries in the combat environment and used to develop suitable mitigation strategies.

Background

Fatigue is one of the most commonly reported symptoms among individuals who have had a TBI. In a longitudinal study by Bushnik, Englander and Wright (2008), participants reported the highest levels of fatigue within 6 months post-injury and showed a pattern of decline in fatigue over the course of a year. Many people who have sustained a brain injury experience difficulty getting to sleep, maintaining uninterrupted sleep, and subsequently daytime fatigue (Drake & Bradshaw, 1999). One study found that about 50 % of TBI patients complain of sleep problems after the initial injury (Parcell et al. 2006). A study by Clinchot et al. (1998), reported that in a group of patients admitted to a rehabilitation unit for TBI, 50 % had difficulty sleeping; 64 % described waking up too early from sleep; 25 % described sleeping more than usual; 45 % described problems falling asleep; and 80 % of patients that reported sleep problems also reported problems with fatigue. The researchers found the more severe the brain injury, the more likely the patient is to have a sleep disturbance; patients who had sleep disturbances were more likely to have problems with fatigue, and females were more likely to have trouble with sleep. Similarly, Beetar, Guilmette, and Sparadeo (1996) surveyed a sample of mild ($n = 127$), and moderate to severe ($n = 75$) patients with TBI, and a general neurologic (non-TBI) group ($n = 123$) referred for neuropsychological assessment. They found TBI patients had significantly more insomnia and identified poor sleep maintenance as the most common sleep problem. The reason TBI interferes with sleep is two-fold. First, TBI is likely to cause sleep disorders directly, by damaging the areas of the brain closely associated with sleep-wake mechanisms (septum pellucidum, corpus callosum, deep gray matter, and dorso-lateral pons, and midbrain; Verma, Anand, & Verma, 2007). Second, research has shown that pain at night is an important factor in nocturnal sleep disruption and daytime sleepiness (Guilleminault, et al., 2000).

Dynamic entry, or breaching, refers to the use of explosives as a method to gain access to fortified structures. In both training and operations, Warfighters are repeatedly exposed to blast events in the course of carrying out their duties. Because breachers apply explosives as a means of gaining access to barricaded or hardened structures, these specialists can be exposed to as many as a dozen 0.3 to 10 pound charges per day during training exercises, and even larger numbers per night during military operations. There is growing concern that repeated blast exposures may cause health problems for U.S. Soldiers. Anecdotal complaints by breacher instructors stateside, including sleep pattern disruption, chronic headaches, and short-term memory loss, closely resemble symptoms suffered by our Warfighters in Afghanistan and Iraq (Welch, 2005).

The present study recruited participants from the USMC Methods of Dynamic Entry School in

Quantico, VA. The basic course runs Monday to Friday of the first week and Monday to Friday of the second week, combining classroom and field training. A number of variables dictate the specifics of each course such as weather, number of students, and scheduling conflicts. However, an example course schedule is provided in table 1.

Table 1. An example schedule for the basic Methods of Dynamic Entry course.

Day	Activity
1 (Mon)	Classroom
2 (Tue)	Classroom in AM, Range in PM for non-blast entry training
3 (Wed)	Classroom in AM; PM at range for first blast charges (single door and window entry)
4 (Thu)	Classroom in AM; mid-morning through PM at range for blast charges (door entry, fence, and gun-port, a two-team coordinated event)
5 (Fri)	Classroom testing in AM; Range in PM for blast charges (roof and double entries, exterior + interior doors)
6 (Mon)	Remakes of testing in AM; Mid morning and PM at range for largest charge day (Cinderblock wall, stand alone structures; Reinforced concrete wall; Double entry)
7 (Tue)	Range day for practicals (may include a short amount of classroom time) Practicals are scenarios given to the students in order to test their process, planning, techniques, and solution to the scenario (it may combine any and all techniques and entries learned to date). Basically one house at time is used with two entries needed (could be window+door or ext+int door or etc).
8 (Wed)	Range day for practicals. Usually completed mid-day or early afternoon. A night-time breaching exercise is planned for once it is dark. This is an entire mission (starts from some point remote from target locations and instructors create diversions/hostiles).
9 (Thu)	Range clean-up
10 (Fri)	Graduation

Research objectives and hypotheses

Given the number of Soldiers returning from Iraq and Afghanistan with a probable TBI (Tanielian & Jaycox, 2008), the well documented link between TBI and fatigue (e.g., Bushnik, Englander, & Wright, 2008), and anecdotal complaints of sleep problems by USMC breachers (V. C. Chancey, personal communication, January 12, 2009), the objective of this study was to evaluate changes in sleep quantity and quality, as well as changes in daytime sleepiness, in USMC breachers (both students and instructors) participating in a USMC Methods of Dynamic Entry School training period.

It was predicted that the data would reflect reported complaints such that sleep disruptions (measured with actigraphy watches) and daytime sleepiness would increase over the course of a training period and self-reported quality of sleep would decline. It is important to note that this

study is preliminary in nature and driven by anecdotal evidence rather than theoretically constructed research questions and hypotheses. Resources were limited for this study and did not allow for a number of potentially confounding factors to be experimentally controlled. However, the investigators attempted to unobtrusively document these factors through self-report procedures. The results and conclusions of this study are thus quite limited but provide foundation and recommendation for future study.

Methods

Participants

A total of 18 participants (response rate = 100%) were recruited from the USMC Methods of Dynamic Entry School. All participants were male, with a mean age of 26 years. Four of the participants were instructors of the course (age range of 25 to 30 years) and 14 participants were students in the course (age range of 19 to 33 years). All participants provided written informed consent. Information about medical factors which may impact sleep patterns (e.g., medications, sleep disorders) was obtained by means of a self report questionnaire. Twelve participants reported regular use of tobacco products, 14 reported regular alcohol use (weekly), 15 reported daily caffeine intake, 2 reported taking over the counter drugs for sinus congestion, 1 reported the use of prescription medication for allergies, and 3 reported use of dietary supplements. With regard to medical history, 5 reported a head injury and loss of consciousness (none of which occurred in the past 3 years), 2 reported shortness of breath, 1 reported chest pain, 3 reported a rapid heart rate, 2 reported high blood pressure, 3 reported dizziness, 1 reported seizures in childhood, 1 reported headaches associated with a head injury, and 2 reported trouble sleeping. None of the reported conditions were current or on-going with the exception of one participant who reported current difficulty sleeping. The protocol was reviewed and approved by the USAMRMC HSRRB prior to implementation.

Study design and procedure

This study employed a within-subjects design. During the USMC Methods of Entry School training period (which lasted 12 days), participants were evaluated on sleep disturbances at start, mid-point, and end of the course. Participants wore Actiwatches for the duration of the breacher training course and completed an Actiwatch log (appendix A). Participants completed three subjective measures of sleep quality and quantity at the beginning of training (Day 1 of training course), mid-point (Day 5 of training course), and final day (Day 12 of training course). Each administration of the questionnaires took approximately 15 minutes. On the final day of the training course, all data from the Actiwatches was downloaded by a qualified member of the research team.

Research Assessment Tools

Actigraphy watches

Wrist activity monitors collect human activity data on a minute-by-minute basis and are an acceptable substitute for use under circumstances where Electroencephalography (EEG) is not

practical (e.g., Killgore et al., 2009). These monitors yield data which estimate the wearer's total sleep, sleep efficiency, sleep latency, number of sleep bouts, mean length of sleep bouts (time in seconds), number of immobile minutes, number of immobile phases, and mean length of immobility (time in minutes). The device used in the present study is the Actiwatch which is manufactured by Mini Mitter, a Respironics Company. As described in Killgore, et al., the Actiwatch® is a:

> small, lightweight, limb-worn, device which utilizes an accelerometer to monitor the occurrence and degree of motion. The sensor integrates the degree and speed of motion and produces an electrical current that varies in proportional magnitude at a sampling rate of up to 32 Hz. It contains an omnidirectional sensor and is thus, sensitive to motion in all directions. Once collected, the data is wirelessly downloaded to a reader which is connected to a personal computer. Accompanying Actiwatch® software allows the manipulation, analysis, and presentation of the data. The standard Actiwatch® is a durable device which was used in Iraq under actual combat conditions. It has been designed with a water-resistant case for use at pressures up to 1 atmosphere (p. 6).

Self-report measures

To supplement the data from the actigraph, sleep quantity and quality was assessed using subjective measures of sleep including the Epworth Sleepiness Scale (Johns, 1991; appendix B), Stanford Sleepiness Scale (Hoddes, et al., 1973; appendix C) and the Sleep Timing Questionnaire (Monk, et al., 2003; appendix D) during the training session. The Sleep Timing Questionnaire was administered at the beginning of the training course to capture the pre-training sleep patterns/habits of participants. The mid-point administration captured sleep patterns/habits during the first half of training and the end point administration captured the second half of the training session. The Sleep Timing Questionnaire was slightly modified to gain information on potential confounds (e.g., jet lag, alcohol consumption).

Results

Given the limited number of instructors in this preliminary study, data from instructors and students were combined for the statistical analysis. However, the exposure histories between instructors and students are extremely different and should be explored in the future. To illustrate this discrepancy, the descriptive data from instructors and students were separated for graphical representations.

Actigraphy data

Raw data from the Actiwatches were analyzed using the accompanying software from Mini Mitter Co., Inc. This software program allowed each data file to open as an actogram (visual display of the activity-rest patterns). Using the raw actigraphy data as well as the inputted information provided in the Actiwatch data logs maintained by the participants, the program algorithm calculated a number of dependent variables including total sleep (in minutes), sleep efficiency, sleep latency, number of sleep bouts, length of sleep bouts (time in seconds), number

of immobile minutes, number of immobile phases, and length of immobility. Data points above or below three standard deviations from the mean were filtered. The relationship between each dependent variable and the 12-day training period was analyzed using bivariate correlation which yielded no significant results.

Subjective assessments

The subjective assessments were scored and analyzed using repeated measures analyses of variance (ANOVAs) and subsequent paired samples *t*-tests. Six dependent variables were analyzed from the Sleep Timing Questionnaire: normal bed time during the week, normal bed time on the weekend, normal wake-up time during the week, normal wake-up time on the weekend, minutes to fall asleep, and minutes of sleep lost due to disturbances (e.g., getting up). In order to analyze differences between bed times and wake-up times, two difference scores were calculated, the difference between reported beginning and midpoint times and the difference between reported beginning and final times. The difference scores were analyzed using one-sample *t*-tests with a test value of 0. Responses to the Epworth Sleepiness Scale did not change significantly across the three test points (beginning, mid-point, and end of training). The Stanford Sleepiness Scale score varied significantly across the test points, $F(2, 34) = 3.61$, $p = 0.04$. Participants indicated increased sleepiness at the end of the course than at the beginning of the course, $t(17) = -2.61$, $p = 0.02$ (figure 3). Results of the sleep timing questionnaire showed that bedtimes and wake-up times did not significantly differ across the training course nor did the amount of sleep lost due to disturbances. However, the number of minutes to fall asleep changed significantly, $F(2, 32) = 4.47$, $p = 0.02$ (figure 4), such that participants reported it took less time to fall asleep at the end of the training than at the beginning, $t(17) = 3.32$, $p = 0.004$. At the mid-point of the course, participants reported less time to fall asleep, however this difference approached significance, $t(17) = 2.03$, $p = 0.058$. Participants also indicated the extent to which they felt behaviors which impact sleep quality and quantity, including stress level and alcohol use, had or had not changed recently. Overall, participants responded that these factors were fairly stable (table 2).

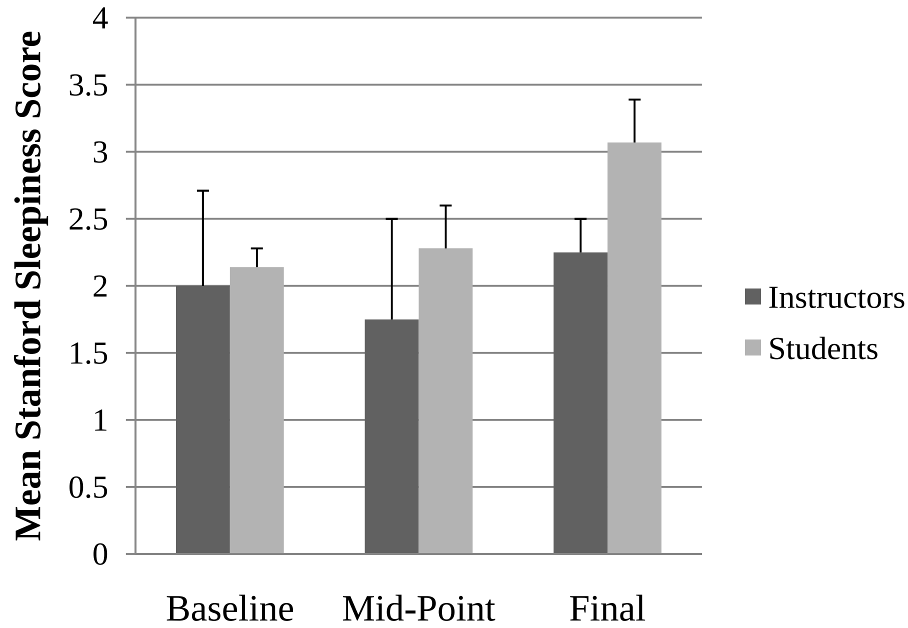

Figure 1. Mean Stanford Sleepiness Scale scores. Error bars represent standard error of the mean.

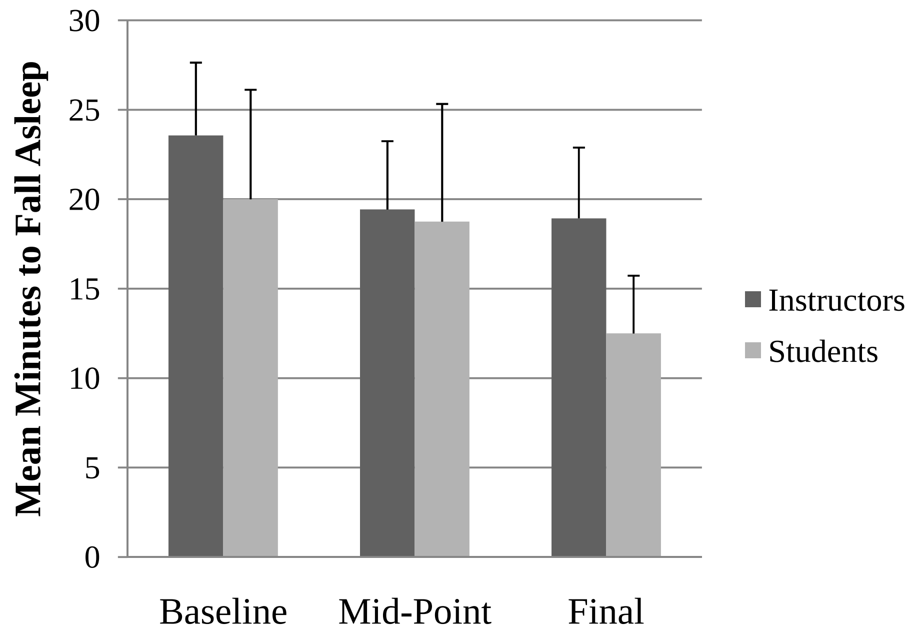

Figure 2. Mean minutes to fall asleep as reported on the Sleep Timing Questionnaire. Error bars represent standard error of the mean.

Table 2. Response frequencies to Sleep Timing Questionnaire.

Recently traveled across time zones?			
Yes	**7**		
No	**11**		
Increased amount of stress?			
	Baseline	**Mid-point**	**Final**
Yes	**5**	**7**	**5**
No	**13**	**11**	**13**
Change in amount of alcohol consumed?			
	Baseline	**Mid-point**	**Final**
Less	**1**	**1**	**0**
Same	**15**	**14**	**13**
More	**1**	**2**	**4**
N/A	**1**	**1**	**1**
Change in amount of caffeine consumed?			
	Baseline	**Mid-point**	**Final**
Less	**2**	**2**	**2**
Same	**15**	**14**	**12**
More	**1**	**2**	**4**

Discussion

The results of this study support anecdotal evidence of sleep disturbances among breachers subjected to periods of blast exposure during training. Specifically, participants reported an increase in daytime sleepiness (as evidenced by scores on the Stanford Sleepiness Scale) over the course of the training period. Participants were asked to provide information on a number of factors which are known to impact sleep quality and quantity. The results of these data show that most participants did not report changes in alcohol consumption, stress levels, caffeine consumption, wake-up times, bed times, or time zone shifts thus suggesting that there is a factor driving this change in perceived daytime sleepiness not specific to the variables listed. Unlike the subjective reports, the results of the actigraphy data show that estimated sleep variables did not significantly change over the course of the training period. However, the convenience sample used for this study may have been insufficient in size to achieve adequate power to detect an effect. While the list of variables which may influence sleep was not exhaustive in this study, it is reasonable to suggest that the results of this study warrant further exploration into the impact that repeated blast exposure has on sleep patterns.

Limitations and Future Studies

One limitation of this study was that the group consisted of both students and instructors who, most likely, have extremely different blast exposure histories. Unfortunately, the small sample size of the instructors (n = 4) did not allow for group comparisons. This is a potentially important distinction to draw in future studies. Likewise, a more detailed quantified degree of blast exposure on each training day may prove to be a better predictor of sleep outcomes than merely “the day of training course.” One intention for this study was the pilot use of the Actiwatches and subjective assessments specifically in breachers during training. It is the recommendation of this study to employ the Actiwatches and subjective assessments in future studies conducted at USAARL such as an upcoming large scale study of multiple aspects of function, including but not limited to sleep, vestibular, auditory, visual, cognitive, and neuropsychological function in breachers.

The major limitation of this study, however, is that there are a number of factors that may impact sleep that could not be experimentally controlled. While it is important that some factors (e.g., alcohol consumption, stress level) were reported to be consistent during the training period, there are a number of other factors that may influence sleep quality. In order to specifically investigate the relationship between blast exposure and sleep, a control group (whether a within-subjects or between-subjects group) is necessary for comparison.

Conclusions

The results of this study serve multiple purposes: 1) as documentation of the lack of changes in sleep quantity or quality in breachers during a period of blast exposure; 2) as documentation of changes in daytime sleepiness in breachers during a period of blast exposure; and 3) as support for the use of Actiwatches and subjective assessments in the future studies of breachers. The results of the study do suggest changes in daytime sleepiness over the course of the training. Thus, further exploration of the effect of blast exposure on sleep is warranted. Also, the findings of this study support the suitability of these instruments for use in future research. In fact, these instruments will be used in an upcoming large scale, longitudinal study of breachers.

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Appendix A.

Actiwatch Log Sheet.

Participant ID number:

Date:

Age: (Yr) **Sex**: Male Female **Experience**: Student Instructor

Directions: This log sheet is designed to help us understand the data that will be collected while you are wearing the Actiwatch. Please write the time of day (e.g., 0600hrs) and the activity (e.g., wake up, go to sleep) under the day of the week (e.g., Sunday). You can modify as needed. This log sheet and the Actiwatch will be collected at the end of the study. Thank you!

Week 1:

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday

Week 2:

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday

Appendix B.

Epworth Sleepiness Scale.

Participant ID number:

Date:

Time:

How likely are you to doze off or fall asleep in the situations described below, in contrast to feeling just tired? This refers to your usual way of life in recent times. Even if you haven't done some of these things recently try to work out how they would have affected you.

Use the following scale to choose the most appropriate number for each situation:-

0 = would never doze
1 = Slight chance of dozing
2 = Moderate chance of dozing
3 = High chance of dozing

Situation Chance of dozing

Sitting and reading . . . .
Watching TV . . . .
Sitting, inactive in a public place (e.g. a theatre or a meeting) . . . .
As a passenger in a car for an hour without a break . . . .
Lying down to rest in the afternoon when circumstances permit . . . . .
Sitting and talking to someone . . . .
Sitting quietly after a lunch without alcohol . . . .
In a car, while stopped for a few minutes in the traffic . . . .

Total . . . .

Appendix C.

Stanford Sleepiness Scale.

Participant ID number:

Date:

Time:

Instructions: This is a quick way to assess how alert you are feeling. Please rate your alertness today (overall day not just how you feel right now) using the scale below.

Degree of Sleepiness	Scale Rating
Feeling active, vital, alert, or wide awake	1
Functioning at high levels, but not at peak; able to concentrate	2
Awake, but relaxed; responsive but not fully alert	3
Somewhat foggy, let down	4
Foggy; losing interest in remaining awake; slowed down	5
Sleepy, woozy, fighting sleep; prefer to lie down	6
No longer fighting sleep, sleep onset soon; having dream-like thoughts	7
Asleep	X

Rating:______________

Appendix D.

Sleep Timing Questionnaire.

SLEEP TIMING QUESTIONNAIRE (STQ)

Participant ID number:

Date:

SLEEP TIMING QUESTIONNAIRE (STQ)

This questionnaire asks about when you normally sleep. We are interested in getting as accurate a picture as we can of the times when you normally go to bed and get up. Please think carefully before giving your answers and be as accurate and as specific as you can be. **Please answer in terms of the past week. Thanks.**

Please think of GOOD NIGHT TIME as the time at which you are finally in bed and trying to fall asleep.

On the night before a work day or school day,
what is your **earliest** GOOD NIGHT TIME? ______:______pm/am

On the night before a work day or school day,
what is your **latest** GOOD NIGHT TIME? ______:______pm/am

On the night before a work day or school day,
what is your **usual** GOOD NIGHT TIME? ______:______pm/am

How different are your GOOD NIGHT TIMES each night before a work day or school day *(circle one)*

0-15mins. 16-30mins. 31-45mins. 45-60mins.
61-75mins. 76-90mins. 91-105mins. 106-120mins.
2-3hours 3-4hours over 4hours

On a night before a day off (e.g. a weekend),
what is your **earliest** GOOD NIGHT TIME? ______:______pm/am

On a night before a day off (e.g. a weekend),
what is your **latest** GOOD NIGHT TIME? ______:______pm/am

On a night before a day off (e.g. a weekend),
what is your **usual** GOOD NIGHT TIME? ______:______pm/am

How different are your GOOD NIGHT TIMES on each night before a day off (e.g. a weekend)? *(circle one)*

0-15mins 16-30mins 31-45mins. 46-60mins.
61-75mins. 76-90mins 91-105mins. 106-120mins.
2-3hours 3-4hours over 4hours

Please think of GOOD MORNING TIME as the time at which you finally get out of bed and start your day.

On a work day or school day,
what is your **earliest** GOOD MORNING TIME? ______:______am/pm

On a work day or school day,
what is your **latest** GOOD MORNING TIME? ______:______am/pm

On a work day or school day,
what is your **usual** GOOD MORNING TIME? ______:______am/pm

How different are your GOOD MORNING TIMES on each work day or school day? *(circle one)*

0-15mins. 16-30mins. 31-45mins. 46-60mins.
61-75mins. 76-90mins. 91-105mins. 106-120mins.
2-3hours 3-4hours over 4hours

On a day off (e.g. a weekend),
what is your **earliest** GOOD MORNING TIME? ______:______am/pm

On a day off (e.g. a weekend),
what is your **latest** GOOD MORNING TIME? ______:______am/pm

On a day off (e.g. a weekend),
what is your **usual** GOOD MORNING TIME? ______:______am/pm

How different are your GOOD MORNING TIMES on each day off (e.g. a weekend)? *(circle one)*

0-15mins. 16-30mins. 31-45mins. 46-60mins.
61-75mins. 76-90mins. 91-105mins. 106-120mins.
2-3hours 3-4hours over 4 hours

These questions are about how much sleep you lose to unwanted wakefulness:

On most night, how long, on average does it take you to fall asleep after you start trying?

____________minutes

On most nights, how much sleep do you lose, on average, from waking up during the night (e.g. to go to the bathroom)?

____________minutes

These questions are about factors which may influence your sleep patterns (Please circle your answers):

Have you recently traveled between multiple time zones (e.g., Asia to USA)?

YES NO

Do you feel that you are under more stress than usual?

YES NO

Has the average amount of alcohol you consume changed?

MORE LESS SAME

Has the average amount of caffeine you consume changed?

MORE LESS SAME

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